



Concepts to Support HRP Integration Using Publications and Modeling

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Introduction



- HRP's role: enabling safe, reliable, and productive human space exploration within and **beyond Low Earth Orbit**.
- Can we increase effectiveness of addressing the risks of getting humans to Mars?
- With limited flight resources, can we provide
 - countermeasures
 - knowledge
 - technologies
 - and tools that

take advantage of **multiple perspectives, disciplines, and complementary solutions?**



As seen in previous talk, initial efforts are underway to enhance HRP's emphasis on integration and cross-disciplinary scientific collaborations.



Use Models and Tools to Support Integration



- To emphasize integration in HRP's science portfolio management, concepts are being explored through development of a set of tools.
- These tools are intended to enable modeling, analysis, and visualization of
 - the state of the human system in the spaceflight environment
 - HRP's current understanding of that state with an indication of uncertainties
 - and how that state changes due to HRP programmatic progress and design reference mission definitions.

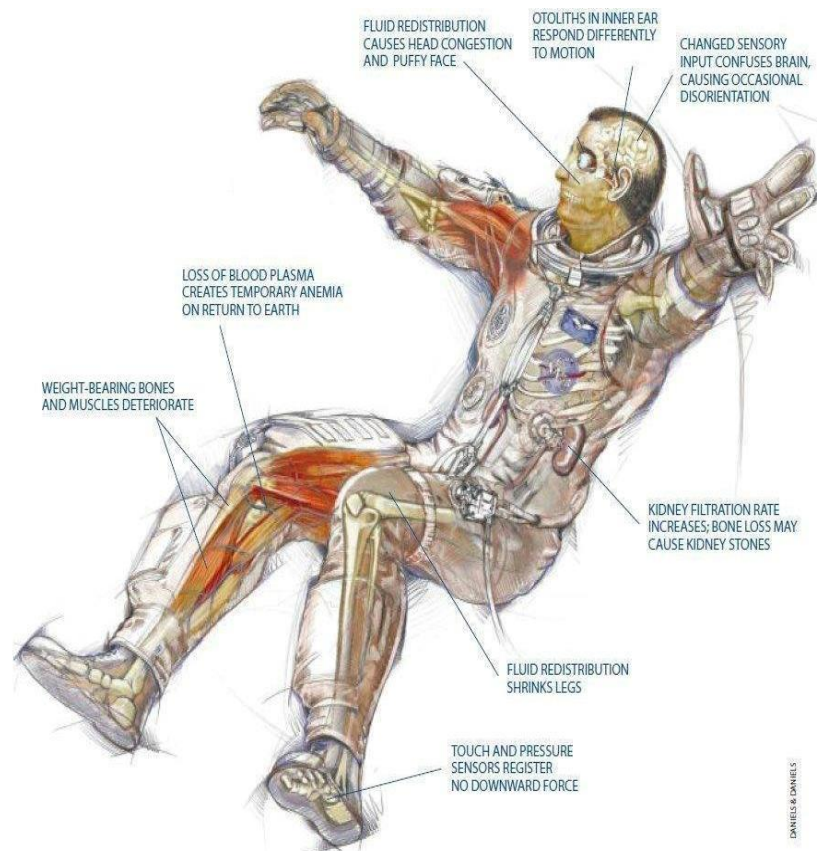


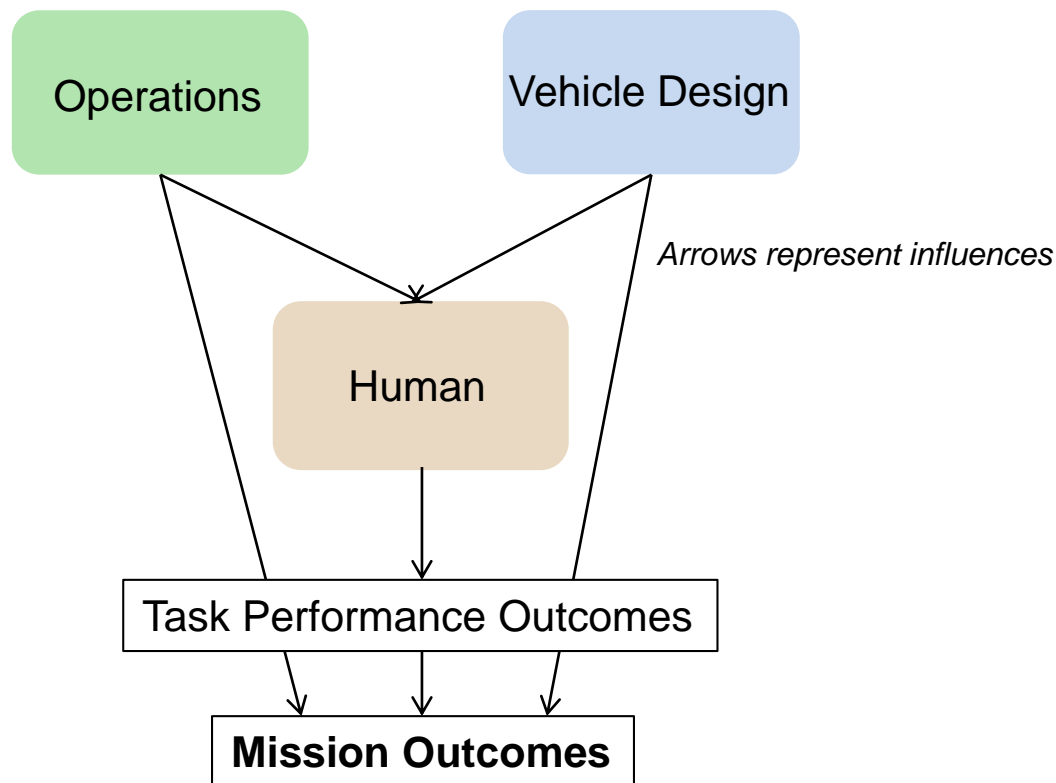
Image from: <http://zerog2002.de/bodyreactions.html>



Initial High-Level Model Framework



- Common goals of safe, productive and reliable human space flight
- Whether focus is on Operations, Vehicle Design or the Human System

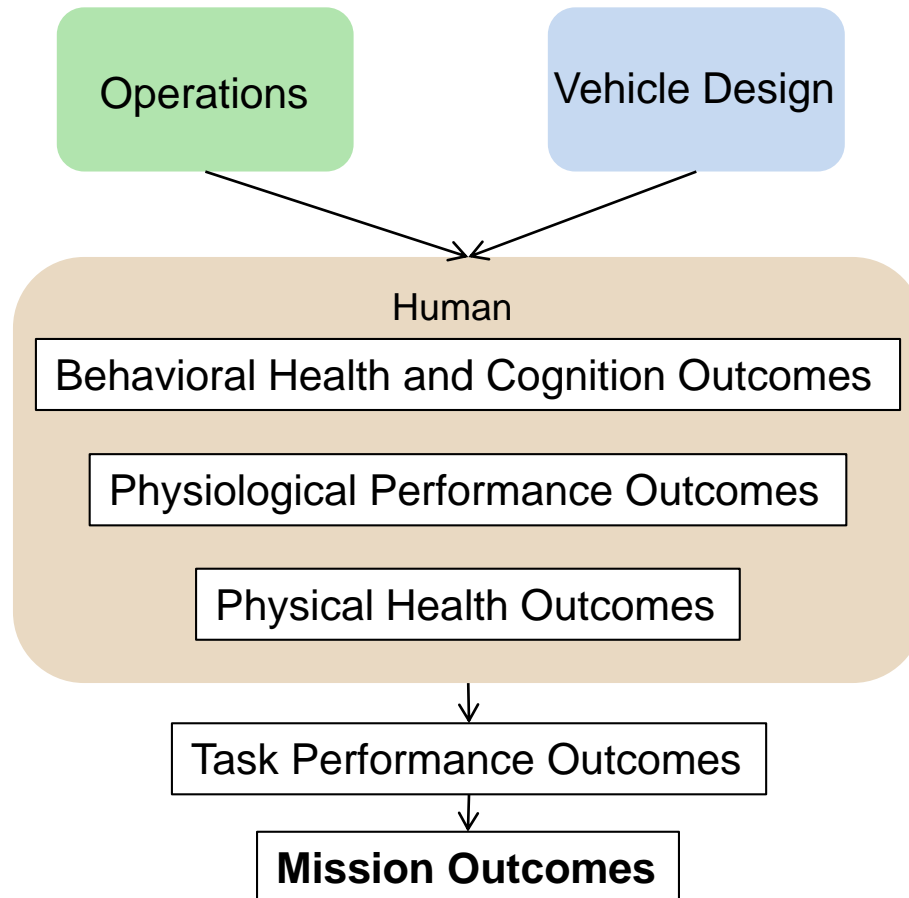




Expanding Framework

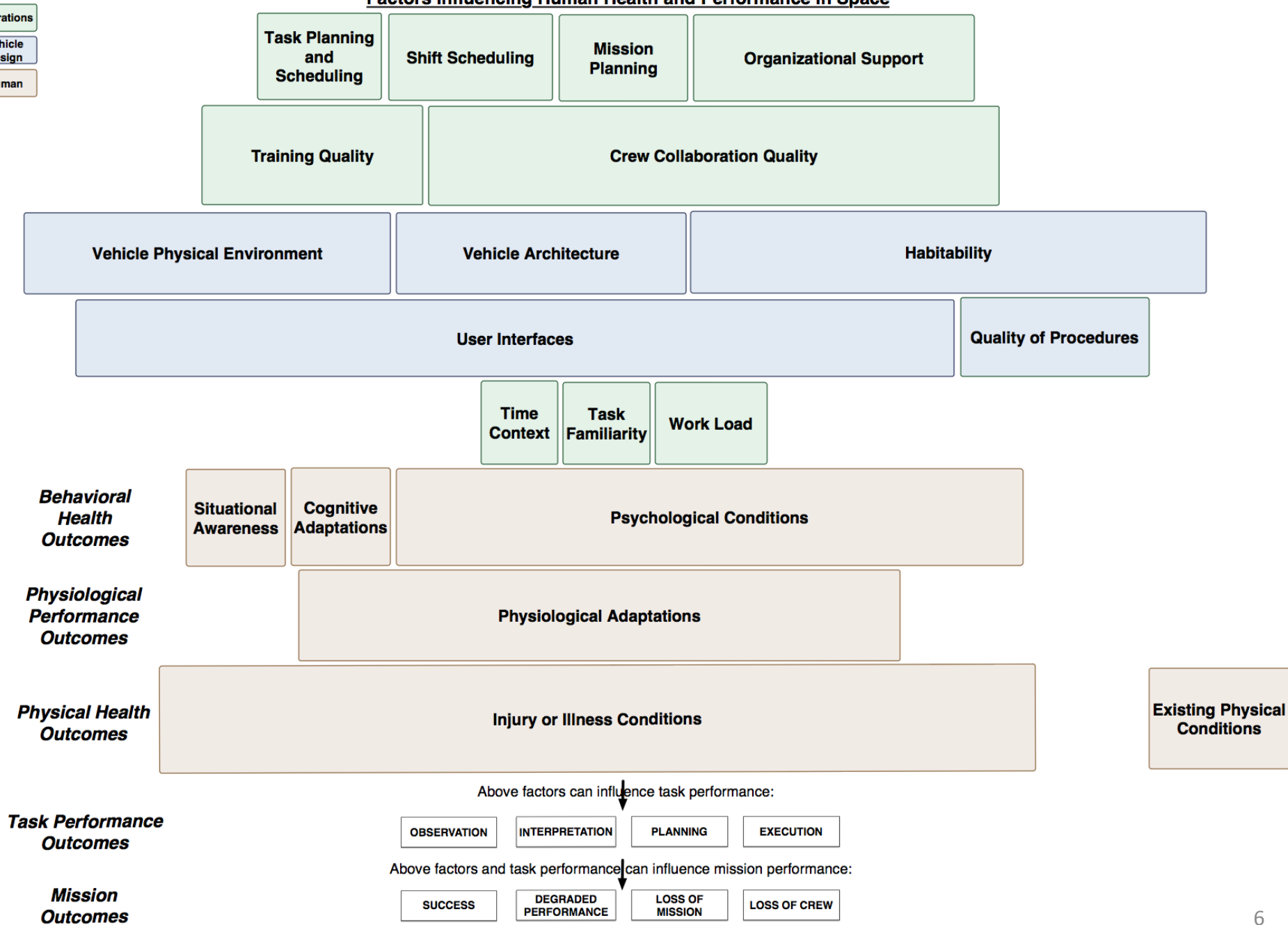


- In the Human System, HRP supports the protection of additional outcomes



Contributing Factor Map

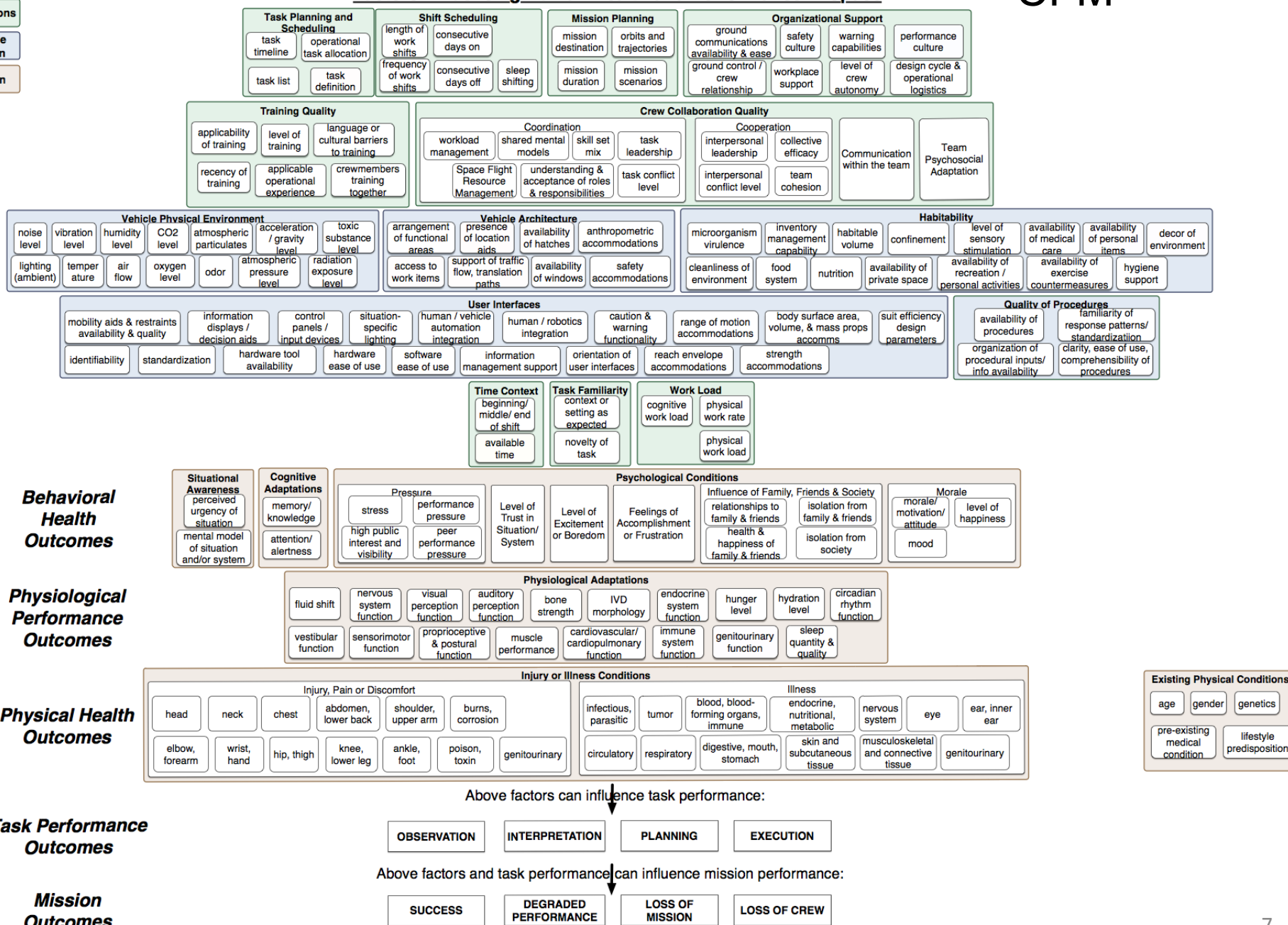
Factors Influencing Human Health and Performance in Space



Contributing Factor Map

Factors Influencing Human Health and Performance in Space

“CFM”





Initial Questions Driving Modeling Approach



➤ Risk Level

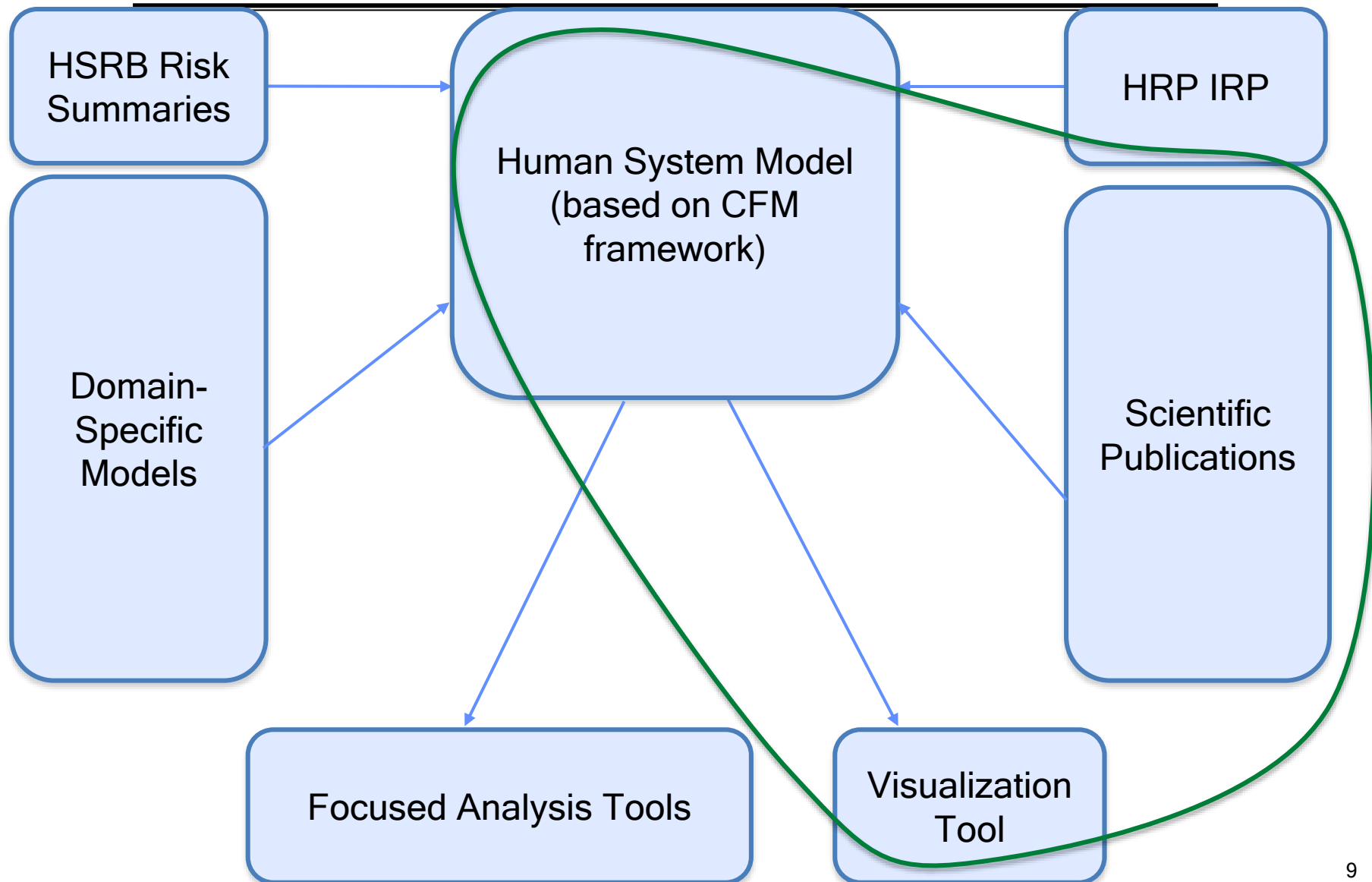
- **Characterization of Work:** What Risks are being addressed?
- **Completeness/Scope:** Have related Risks been adequately addressed in Evidence Reports? In Research Plans (Gaps and Tasks)?
- **Collaborations:** For the Research Plans of related Risks, are there potential collaborations or efforts with information that could be shared?

➤ Factor Level

- **Characterization of Work:** What factors are being addressed?
- For factors that appear influential or high priority (e.g., based on frequency in a relevant search, a sensitivity analysis per Risk, DRM, mission phase...)
- **Completeness/Scope:** Have those factors been adequately addressed in Evidence Reports? In Research Plans (Gaps and Tasks)?
- **Collaborations:** For Risks with the same relevant factors, are there potential collaborations or efforts with information that could be shared?

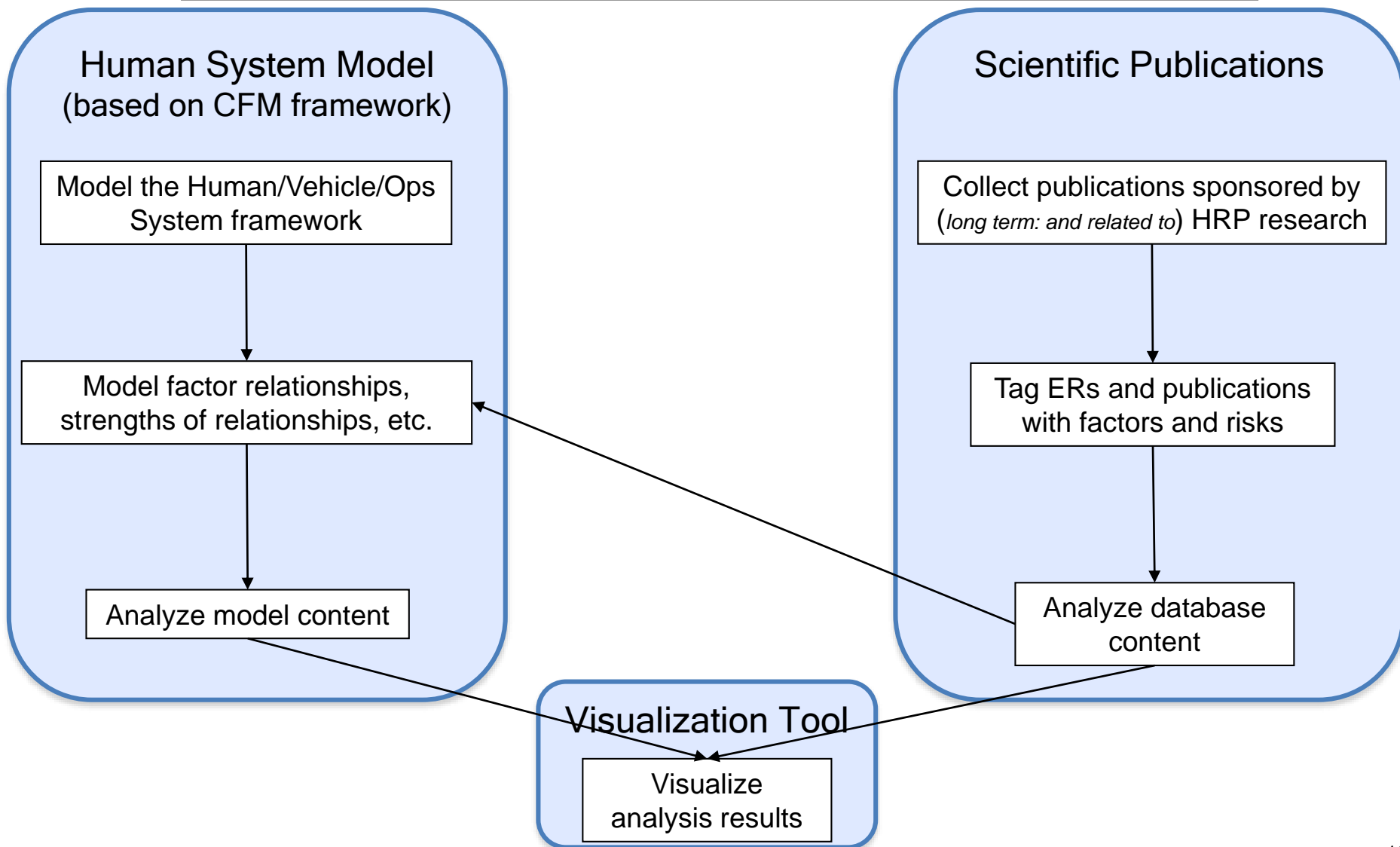


Model for Integration – Information Interface Concepts





Initial Integration Activities





Proof of Concept Work Using Publication Subset



- 2013 Q3 set of publications (~40 publications)
- Tagged with applicable factors and risks

Title	Creator	Date Added	Info	Notes	Tags	Related
Dose- and ApoE Isoform-Dependent Cognitive Injury after Cranial (56)Fe ...	Villasana et al.	1/21/14 2:19:27 PM				
Autosomal mutations in mouse kidney epithelial cells exposed to high-e...	Turker et al.	1/21/14 2:19:27 PM				
Effect of SPE-like proton or photon radiation on the kinetics of mouse pe...	Romero-Weaver et ...	1/21/14 2:19:27 PM				
▶ Lack of genomic instability in bone marrow cells of SCID mice exposed w...	Rithidech et al.	1/21/14 2:19:27 PM				
Effects of whole body (56)Fe radiation on contextual freezing and Arc-po...	Raber et al.	1/21/14 2:19:27 PM				
Effects of (56)Fe radiation on hippocampal function in mice deficient in ...	Raber et al.	1/21/14 2:19:27 PM				
▶ The LET Dependence of Unrepaired Chromosome Damage in Human Ce...	Loucas and Cornfo...	1/21/14 2:19:27 PM				
Comparative Analysis of Cell Killing and Autosomal Mutation in Mouse ...	Kronenberg et al.	1/21/14 2:19:27 PM				
Histone modifications and DNA double-strand break repair after exposur...	Hunt et al.	1/21/14 2:19:27 PM				
Early Effects of Whole-Body (56)Fe Irradiation on Hippocampal Function ...	Haley et al.	1/21/14 2:19:27 PM				
▶ Nontargeted Stressful Effects in Normal Human Fibroblast Cultures Expo...	Gonon et al.	1/21/14 2:19:27 PM				

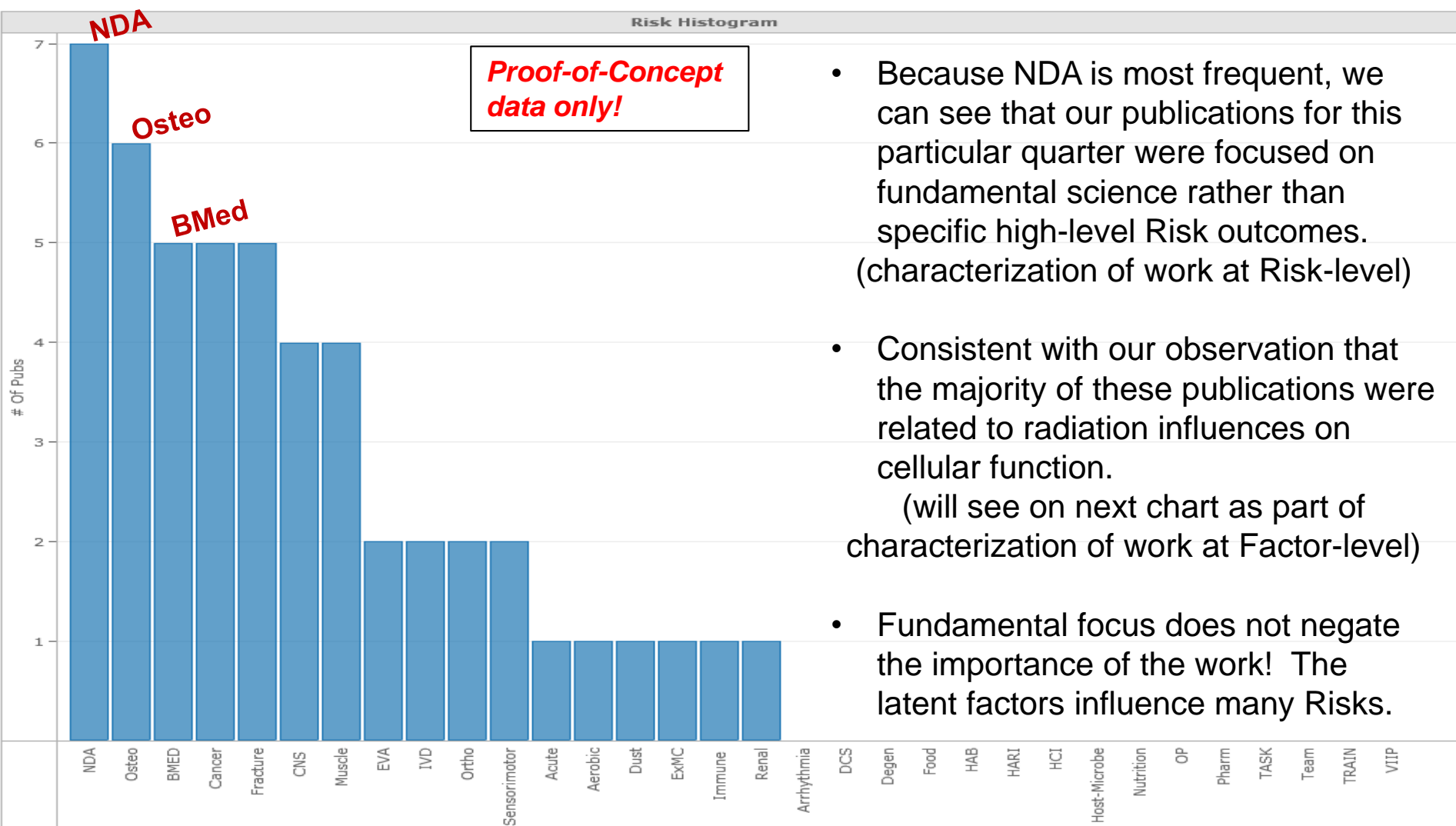
4 tags:

- CFM_Cellular function
- CFM_Radiation exposure
- Risk_NDA
- SR

*NDA = None Directly Applicable



Risk Histogram - Frequency in Sample Publication Set

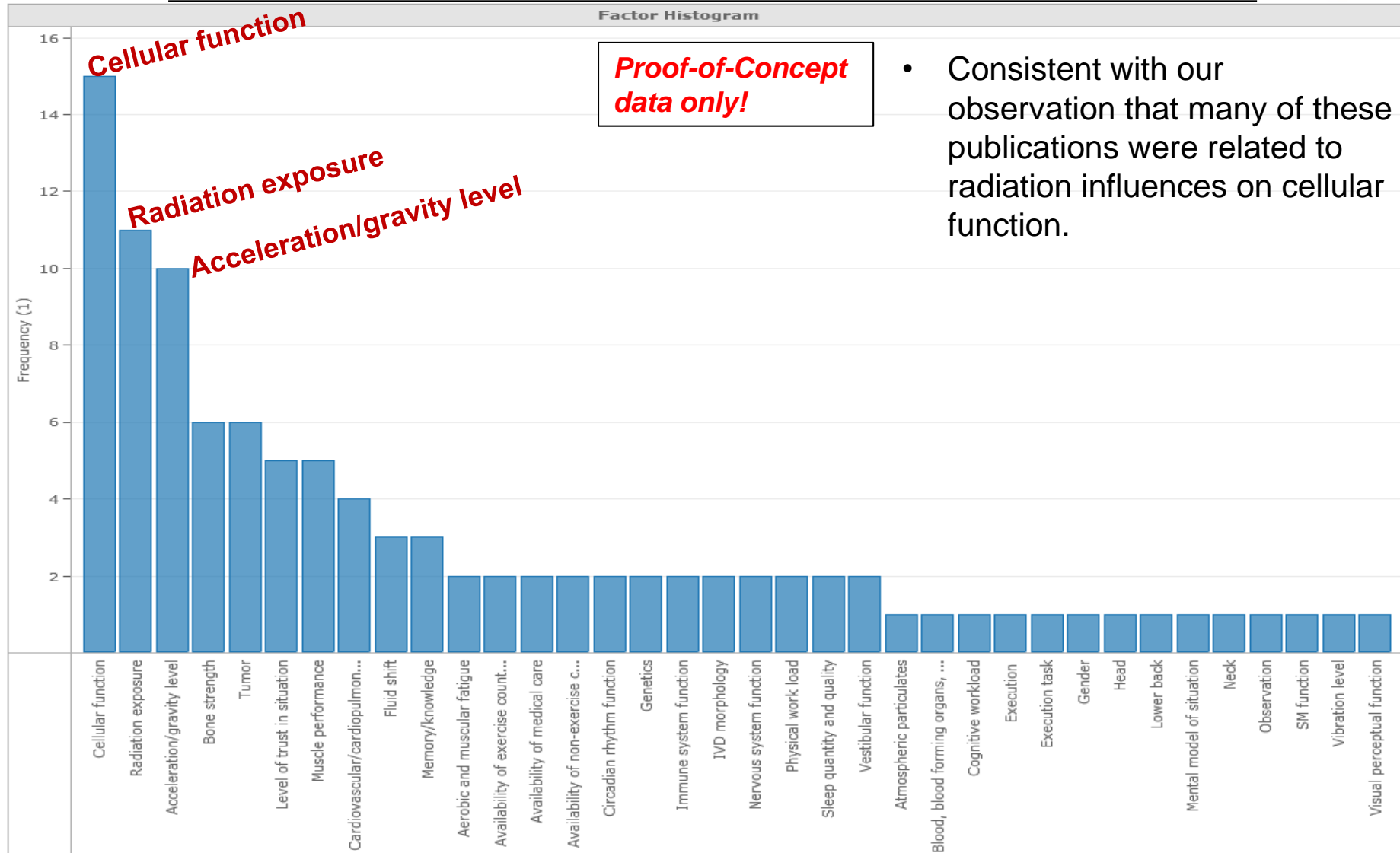


- Because NDA is most frequent, we can see that our publications for this particular quarter were focused on fundamental science rather than specific high-level Risk outcomes. (characterization of work at Risk-level)
- Consistent with our observation that the majority of these publications were related to radiation influences on cellular function. (will see on next chart as part of characterization of work at Factor-level)
- Fundamental focus does not negate the importance of the work! The latent factors influence many Risks.

*NDA = None Directly Applicable



Factor Histogram - Frequency in Sample Publication Set



Factor Histogram Visualized on CFM

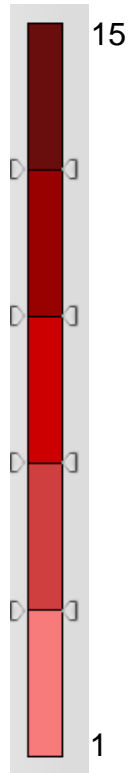
Proof-of-Concept data only!

Domain Key:



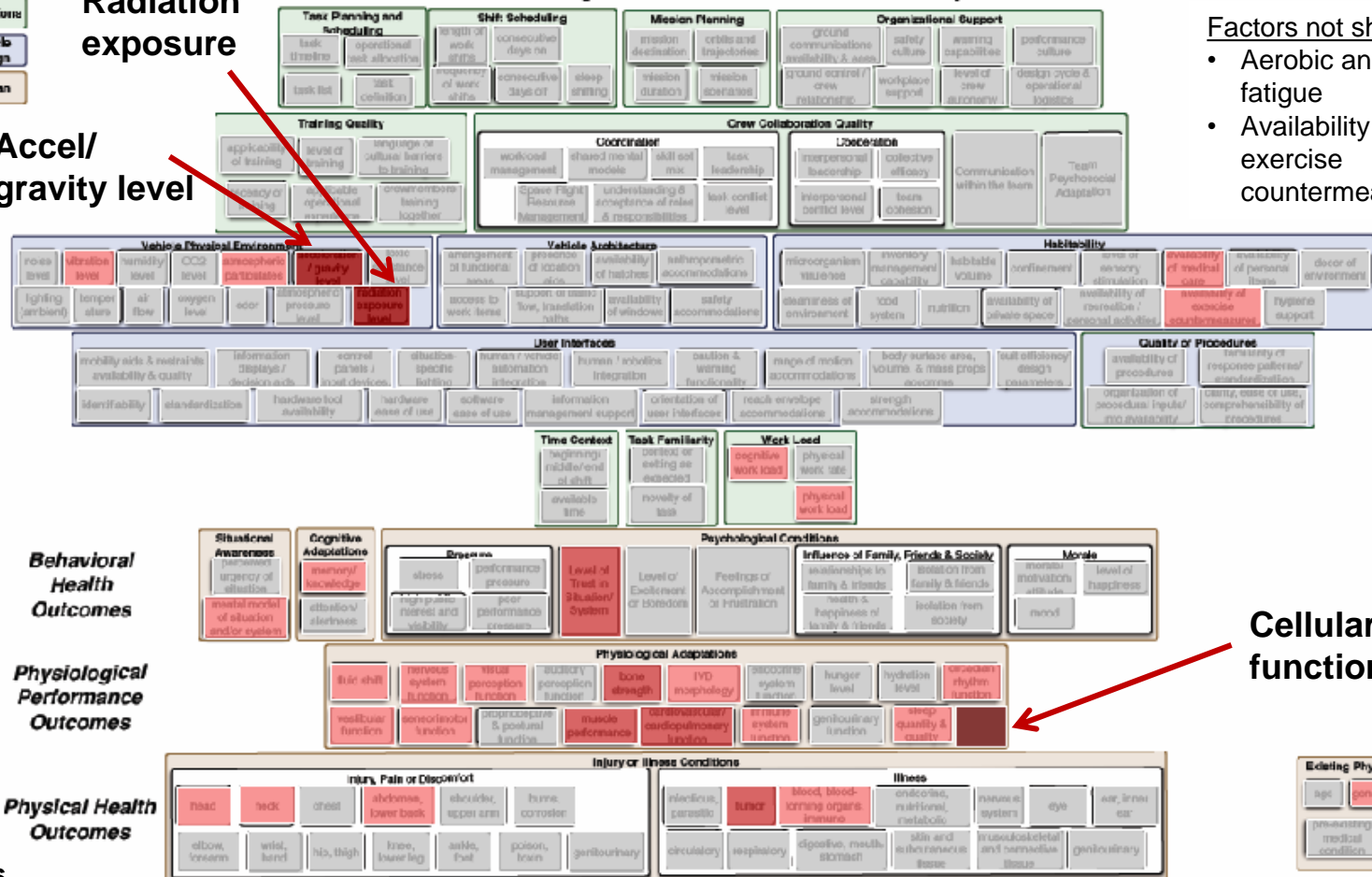
Radiation exposure

Accel/ gravity level



Contributing Factor Map Factors Influencing Human Health and Performance in Space

9/5/13



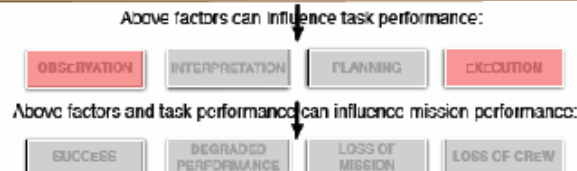
Factors not shown:

- Aerobic and muscular fatigue
- Availability of non-exercise countermeasures

of publications with factor tag

Task Performance Outcomes

Mission Outcomes



Adapted from Mendenhall, J., Development and Application of Spaceflight Performance Shaping Factors for Human Reliability Analysis, University of Colorado, Boulder, CO, 2012.

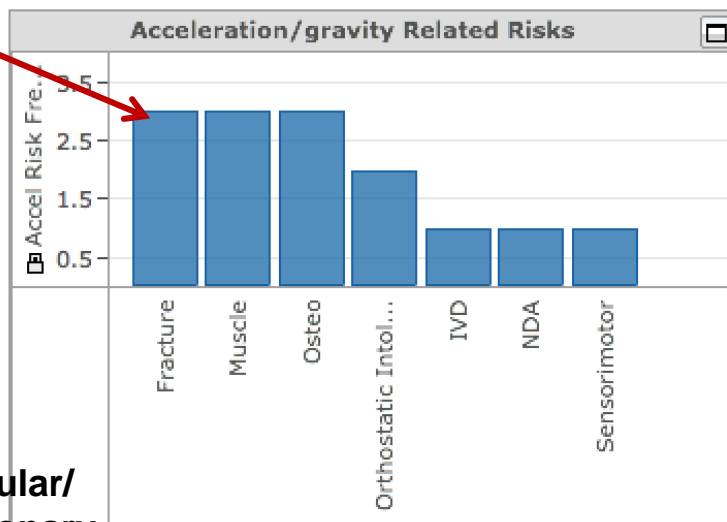


Frequencies of Risks and Factors Associated with Acceleration/Gravity Level

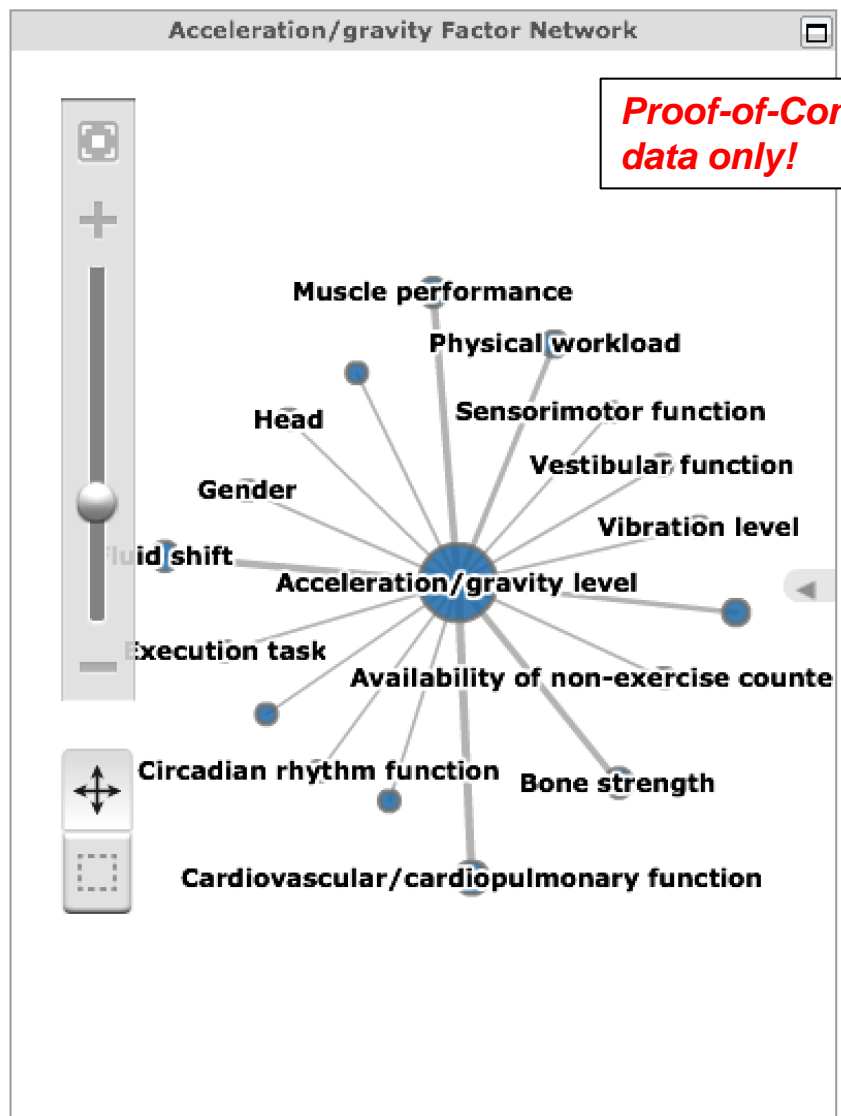
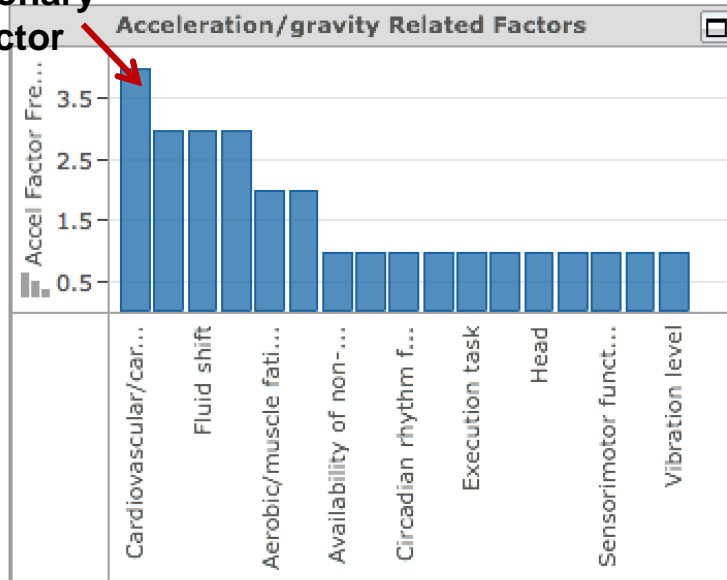


Histograms Radiation Expos... **Acceleration Fact...** Factor Network CFM Overlay

Fracture Risk

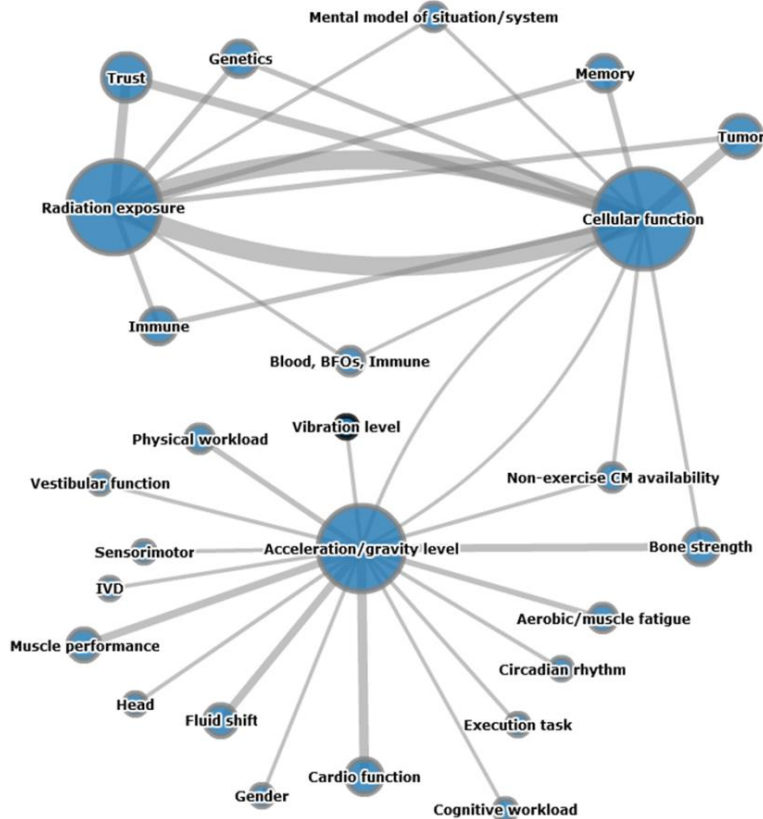


Cardiovascular/
cardiopulmonary
function Factor

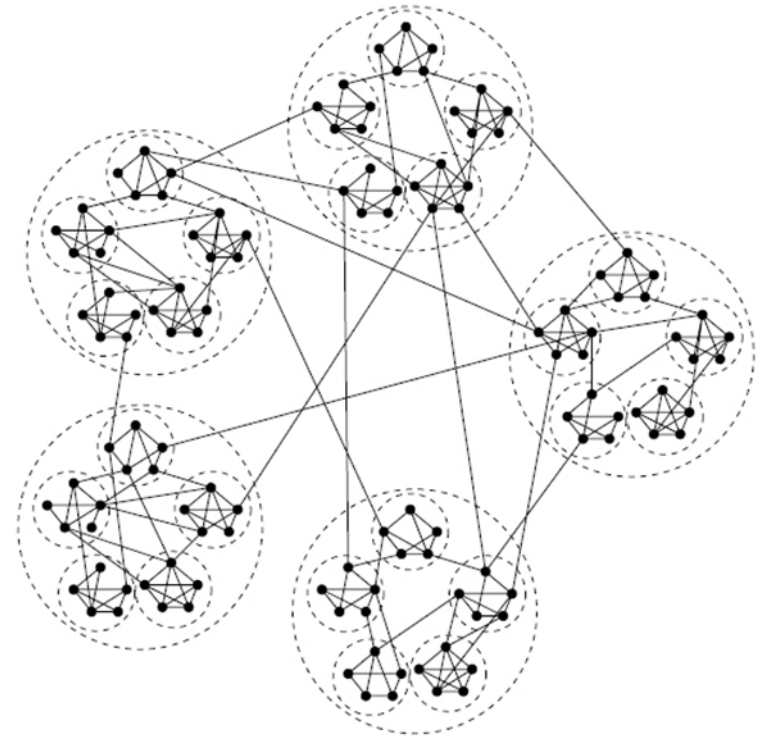




Combined Factor Network for Eventual Network Theory Application



- Proof-of-concept network based on subset of HRP publications



- Small World Network conceptual example

*Use network theory concepts to identify characteristics to enhance, such as **connections to create or strengthen.***



Connecting Multiple Model Inputs to Risks



Community recognizes influential factor

Radiation Exposure Level

Evidence indicates relationship (capture in model)

HRP publications address this factor & its relationships

Cellular Function

Evidence indicates relationship (capture in model)

Tumor

RADIATION RISK

HRP Cancer Risk

Outcome maps to Risks

Bone Strength

Injury (Fracture)

FRACTURE RISK

HRP Fracture Risk

HRP Osteo Risk

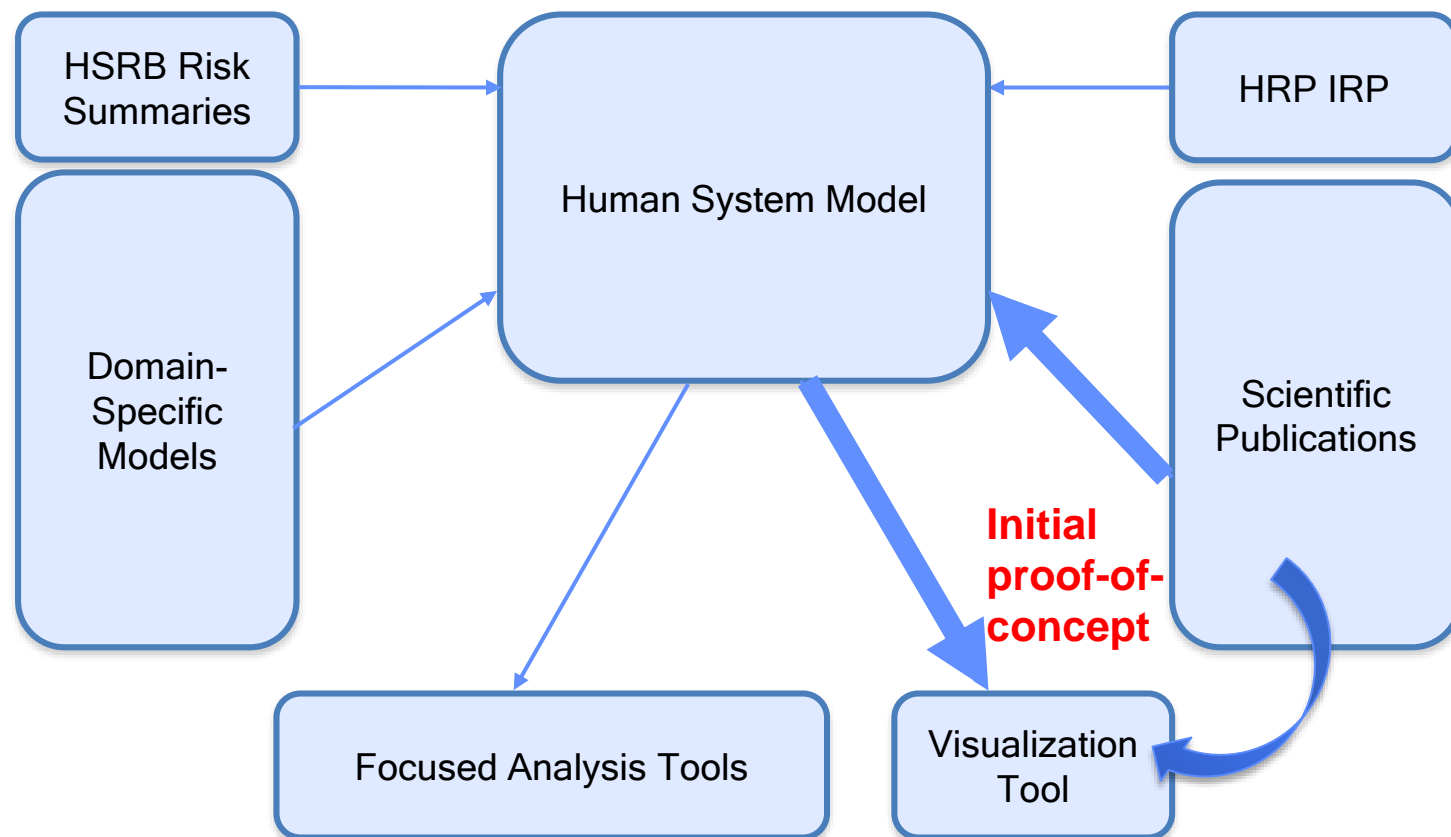
- In this way, fundamental research on cellular function can be shown to support multiple Risks.*
- Additional **collaborative research** may be needed to address important factors and relationships.*



Next Steps Include...



- Develop methods to automate analysis process
- Incorporate information from additional sources into model
- Apply network theory for cross-disciplinary integration enhancement





Questions?



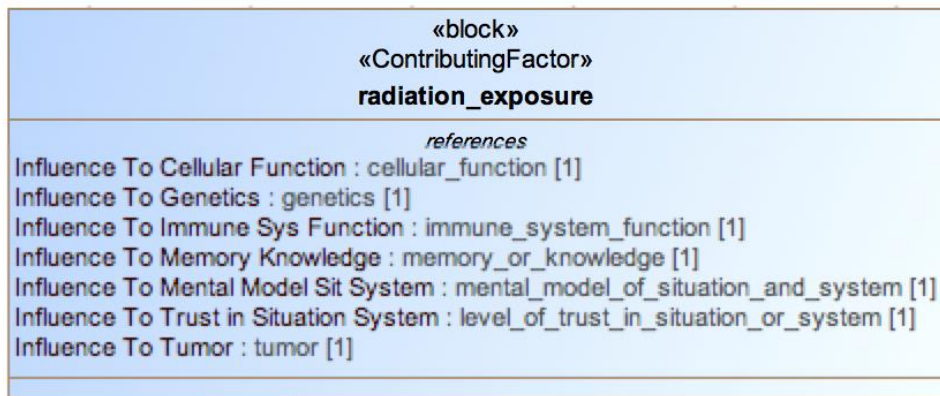
BACKUP



Systems Modeling Language Model as Repository for Factors and Relationships



bdd [Package] 3_Contrib_Factor_Rlns_VIEWS [RadiationExpos_BloodBFOsImmune]



1
Influence From Radiation Expos

Influence To Blood BFOs Immune

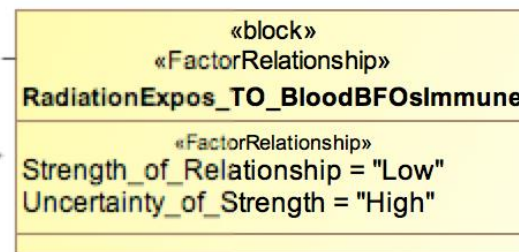
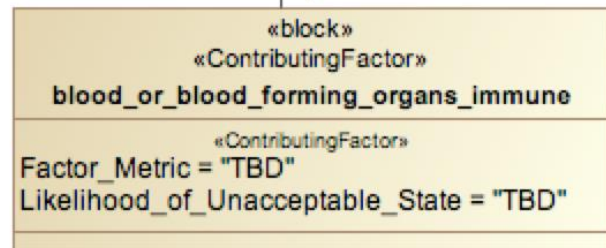




Table of Relationships and Their Attributes



Criteria

Element Type:

...

#	Name	Strength_of_Relationship	Uncertainty_of_Strength
1	RadiationExpos_TO_BloodBFOsImmune	Low	High
2	RadiationExpos_TO_MentalModelSitSystem	Low	High
3	RadiationExpos_TO_ImmuneSysFunction	Med	Med
4	RadiationExpos_TO_Genetics	Med	Med
5	RadiationExpos_TO_Tumor	Med	Med
6	RadiationExpos_TO_MemoryKnowledge	Med	Med
7	RadiationExpos_TO_TrustSituationSystem	High	Med
8	RadiationExpos_TO_CellularFunction	High	Low
9	AccelGrav_TO_Head	Low	High
10	AccelGrav_TO_AvailNonExercisePhysiolCMs	Low	High
11	AccelGrav_TO_CellularFunction	Low	High
12	AccelGrav_TO_ExecutionTaskSuccess	Low	
13	AccelGrav_TO_SensorimotorFunction	Low	
14	AccelGrav_TO_CognitiveWorkLoad	Low	High
15	AccelGrav_TO_CircadianRhythmFunction	Low	High
16	AccelGrav_TO_VibrationLevel	Low	High
17	AccelGrav_TO_IVDMorphology	Low	High
18	AccelGrav_TO_VestibFunction	Low	High
19	AccelGrav_TO_AerobicMuscleFatigue	Med	Med
20	AccelGrav_TO_PhysicalWorkLoad	Med	Med
21	AccelGrav_TO_Cardiovasc_pulm_Function	High	Low
22	AccelGrav_TO_MusclePerformance	High	Low
23	AccelGrav_TO_BoneStrength	High	Low

Not real values